

## **Friction Welding Machine and Operating Method**

The present invention pertains to a friction welding machine and an operating method with the features in the preambles of the principal process claim and the principal device claim.

Such a friction welding machine is known from practice and is used to weld together two workpieces. It comprises a frame with a stationary headstock, which has a spindle with a workpiece holder for the first workpiece and a spindle drive. The second workpiece is mounted with a second workpiece holder, which is connected to a feed drive, which ensures the feed, the frictional feed and the forge stroke. The second workpiece holder is arranged nonrotatingly in the prior-art friction welding machine. The prior-art friction welding machines are designed for certain workpiece sizes and have a limited field of application. Different friction welding machines are necessary for greatly different workpiece sizes.

The object of the present invention is to show a better friction welding technique.

This object is accomplished by the present invention with the features in the principal process claim and in the principal device claim. The double-spindle machine being claimed and the operating method being claimed have the advantage of increased field of application. It is suitable for a substantially broader range of workpiece sizes. This is also beneficial for accuracy.

The spindle diameters may be equal or different. The smaller spindle for the smaller components can be mounted more accurately than the large spindle and it offers a correspondingly greater

precision.

To withstand the strong force forces and torques, bridges may be present, which support the workpiece holders at the housing of the headstock preferably in a positive-locking manner and relieve the spindle. This offers advantages especially in case of the smaller spindles, but it is also favorable in case of spindles of equal size. The bridge may be replaceable and arranged optionally at one or the other of the spindles or at the headstock. The bridge is provided with a workpiece holder, which is mounted rigidly at a carrying body and is replaced with the spindle-side removable workpiece holder.

The friction welding machine being claimed offers, furthermore, advantages for controlling and affecting the friction welding process. The two spindles may rotate in opposite directions, so that the speed of rotation acting at the site of friction may be greater than in prior-art machines. On the other hand, the individual velocities of the two spindles can be reduced due to the addition of the velocities, which makes it possible, on the one hand, to reduce the size of the spindle drives and makes possible, on the other hand, a faster braking. The friction welding process can be correspondingly controlled more sensitively and accurately. Advantages also arise for the angular positioning of the workpieces in the welding position. A workpiece can be held nonrotatingly with the stationarily supported bridge while it is uncoupled from the spindle.

Despite the fact that the fields of application and the range of workpieces are enlarged due to the double spindles, the friction welding machine makes do with a uniform feed drive, which covers all fields of application.

The drive technology for the two spindles and the headstocks may have the same design or different designs. The fields of application of the spindle drives can also be expanded and adapted to workpieces of different sizes and weights by means of flywheel masses that can be set or coupled. The friction welding machine may be operated now optionally with direct drives or with flywheel drives.

Additional advantageous embodiments of the present invention are described in the subclaims.

The present invention is schematically shown in the drawings as an example. Specifically,

Figure 1 shows a schematic side view of a double-spindle friction welding machine,

Figure 2 shows a variant of the friction welding machine from Figure 1 with flywheel drives and a bridge for welding large workpieces,

Figure 3 shows a cut-away view of the spindles in the variant for welding small workpieces, and

Figure 4 shows a side view of a bridge.

Figures 1 and 2 show a friction welding machine (1) designed as a double-spindle machine and two design variants, which differ in terms of the spindle drives (12, 13).

The friction welding machine (1) comprises in both cases a frame (2), which has a machine bed (3) and an upright column (4) at one end. A first, preferably stationary headstock (5) or spindle head, which has a spindle (8) with a workpiece holder (22), preferably a chuck, and with a spindle drive (12), is mounted stationarily on one side. The chuck (22) receives the first workpiece (23).

5 A second headstock (6) or spindle head with a second spindle (9) and with a spindle drive (13) of its own as well as with a second workpiece holder (22) for receiving the second workpiece (24) is arranged opposite the first stationary headstock (5) at a spaced location. The second headstock (6) is mounted movably at the frame (2), especially at the machine bed (3), by means of a traveling carriage (7). The second headstock (6) is connected to a feed drive (25) on the rear side.

10 In the embodiment being shown, the second, mobile headstock (6) has a spindle (9) that has a smaller diameter and can be loaded with a lower load and preferably also a weaker spindle drive (13) than the stationary headstock (5). The smaller spindle (9) is correspondingly mounted more accurately than the large spindle (8). The spindles (8, 9) with the chucks (22) have a common central axis, with which the feed drive (25) is also flush.

15 In a variant of the embodiment shown, the second spindle (9) may have the same size and the same mounting as the first spindle (8). The spindle drives (12, 13) may also have a similar design and be dimensioned for the same strength and load-bearing capacity. The great similarity of the spindle drives (12, 13) may also be given in case of different spindles (8, 9) in another variation.

The traveling carriage (7) is mounted and guided in a positive-locking manner along the direction

of feed (32) by means of a carriage guide (31) at the frame (2) or the machine bed (3). The mounting absorbs the tilting moments that may act.

The feed drive (25) is arranged and supported behind the mobile headstock (6) at said column (4). The feed drive (25) ensures, on the one hand, the rapid feed of the mobile headstock (6) from the withdrawn inoperative position shown in Figure 1 into the advanced working position, in which the two workpieces (23, 24) are brought into aligned frictional contact and rotated in relation to one another. The feed drive (25) ensures, furthermore, the frictional feed and ultimately also the forge stroke, with which the workpieces (23, 24) are abruptly connected. The feed drive (25) may have any desired and suitable design. In the exemplary embodiment shown, which is shown in greater detail in Figure 2, it has two hydraulic cylinders (26, 28). The cylinder (28) located in the rear in the direction of feed is a quick motion cylinder, which is connected to an forge rod (27). As an alternative, the feed drive (25) may also be an electric motor drive or have any other desired design.

To support the strong forge forces, which may be, e.g., between 20 and 100 tons or more, the stationary headstock (5) and the column (4) are connected to one another by one or more axial tie rods (29) in the direction of feed and forging (32) and mutually supported. The frame (2) can be relieved as a result.

The spindle drives (12, 13) may have any desired suitable design and optionally also different designs. In the exemplary embodiment being shown, both spindle drives (12, 13) have an electrically controllable drive motor (14, 15), which acts on the corresponding spindle (8, 9) via an intermediate gear. This is a direct drive in the exemplary embodiment according to Figure 1, and

the intermediate gear (16) is coupled directly with the respective spindle (8, 9).

Figure 2 shows a variant of the drive design with a freely selectable possibility of engaging one or more flywheel masses (17, 18). The flywheel masses (17, 18) can be uncoupled when needed, so that the above-mentioned direct drive is present.

5 One or two, and optionally even more settable flywheel masses (17) may be arranged coaxially with the spindle (9) in the case of the mobile headstock (6) with the smaller spindle (9) and the smaller chuck (22). The flywheel mass (17) can be engaged and connected to the spindle (9) individually or together via a corresponding coupling.

10 More flywheel masses (17, 18) are present at the stationary headstock (5) with the large spindle (8), and these flywheel masses also offer a broader range of possibilities of engagement. Similarly to the smaller headstock (6), two or more settable flywheel masses are arranged at the rearward end of the spindle (8), and these flywheel masses can be directly connected to the rearward end of the spindle (8). The large spindle (8) may, furthermore, be mounted in another column part at the rearward end and connected to a downstream gear mechanism (21) via a shiftable coupling means  
15 (20). A connection (19) that is rigid in terms of rotation may be inserted here. The gear mechanism (21) is connected, on the one hand, at the rearward end, to an arrangement of a plurality of additional flywheel masses (18), which are designed as flywheel masses of different sizes and weights that can be engaged individually. The individual flywheel masses (18) can be braked and fixed when needed by means of stopping brakes (30).

One or both spindles (8, 9) may be equipped with bridges (10, 11), which are inserted between the workpiece holders or chucks (22) and the adjoining wall of the headstock (5, 6) and support the forge and compressive forces  $F$  as well as torques  $M$  acting on the chuck (22) to relieve the corresponding spindle (8, 9) at the headstock housing. The bridges (10, 11) are arranged at the  
5 respective nonmoving spindle (8, 9).

Figure 2 shows the embodiment for welding large and heavy workpieces (23, 24). The large spindle (8) rotates at the stationary headstock (5) in this variant. The opposite small spindle (9) is supported and relieved by the bridge (11) rigidly in relation to the housing. The bridge (11) may optionally also now hold the chuck (22) nonrotatingly.

10 The other arrangement for welding smaller workpieces (23, 24) is shown in the variant according to Figure 3. The smaller spindle (9) moves in this case at the mobile headstock (6). A bridge (10), which relieves the large spindle (8), is arranged at the larger, stationary headstock (5) between the chuck (22) and the headstock housing. In a variant of this embodiment, the large bridge (10) may optionally be done away with and the large spindle (8) can be stopped only with a suitable brake  
15 during forging. The spindle mount may be designed to be so robust that it withstands the mostly reduced forge forces for smaller workpieces even without a bridge (10).

The double-spindle friction welding machine (1) may be operated in different modes of operation. Only one spindle (8, 9) rotates in the conventional modes, while the respective other spindle (9, 8) is stopped nonrotatingly by a brake. Only the respective rotating spindle drive (12, 13) is  
20 correspondingly actuated by the machine and process control (not shown). It is possible in a third

mode to allow both spindles (8, 9) to rotate, which happens, e.g., in opposite directions. The opposite velocities add up as a result at the friction site to a high relative speed of rotation of the workpieces (23, 24). Both spindles (8, 9) are correspondingly braked at the end of the friction process and before the forge stroke, and weaker braking forces are necessary due to the reduction of the individual speeds of rotation, or faster braking is possible. Only the one, rotating spindle (8, 9) is braked at the end of the friction process in the first two modes of operation.

In another variation, the spindles (8, 9) may also rotate in the same direction if needed, and the corresponding spindle (8, 9) is also carried in a frictionally engaged manner by the other, driven spindle (9, 8) if one spindle drive (12, 13) is switched off.

Figure 4 shows a design embodiment of a bridge (11). It comprises an, e.g., plate-shaped carrying body (33), on the front side of which a workpiece mount (22) is rigidly mounted. A positive-locking support (34) is present on the rear side for connection to the headstock (5, 6). This [support] comprises, e.g., the four, rearwardly projecting pins (35) shown, which engage corresponding mounting openings (36) at the headstock (5, 6) in a positive-locking manner. The axial forging or welding forces  $F$  are supported by the flat contact of the carrying body (33) with the headstock (5, 6). The torque or welding moment  $M$  generated during the friction welding is supported by the positive-locking support (34). The spindle (8, 9) is not loaded. The connection of the bridge (11) and the headstock (5, 6) can be secured with a locking mechanism (not shown).

The bridge (11) is replaced in this embodiment with the workpiece holder (22) normally present at the spindle (8, 9). The workpiece holders (22) are attached for this purpose detachably to the



spindles (8, 9) and can be removed to mount the bridge (11). The spindles (8, 9) are arranged and mounted here in their headstocks (5, 6) such that they project axially only slightly if at all over the front wall of the headstock (5, 6) with their front ends when the workpiece mount (22) is removed. The carrying body (33) may otherwise also have a corresponding mounting opening on the rear side. After the workpiece mount (22) has been removed from the spindle (8, 9), the bridge (11) can be mounted on the headstock (5, 6) and placed over the spindle end. The arrangement of the workpiece mount (22) and of the positive-locking support (34) at the bridge (11) is concentric with the aligned spindle axes.

The workpiece mounts (22) at the spindles (8, 9) and at one or more bridges (11) may have essentially the same design. This is favorable in light of the mutual replaceability of the workpiece mounts (22) on the spindles (8, 9). In addition, the same bridge (11) may be attached on one or the other of the headstocks (5, 6) as desired. The headstocks (5, 6) also have similar components of the positive-locking mount (34) for this. It is also advantageous to make uniform the connections between the spindles (8, 9) and the workpiece mounts (22). This makes it possible to mutually replace the workpiece mounts (22). In addition, different types and sizes of workpiece mounts (22) can be arranged on one or the other of the spindles (8, 9) as desired.

Various modifications of the embodiments shown are possible. This pertains to the design embodiment of the headstocks (5, 6), the spindles (8, 9) thereof and the spindle drives (12, 13) thereof. The feed drive (25) may be varied as well. Depending on the value of the forge forces, the tie rod (29) may be done away with in favor of supporting the forces via the frame (2). Furthermore, the size ratios are also variable in the different diameters of the small and large

spindles (8, 9). The first headstock (5) may be mounted movably and lockably at the frame (2).

Furthermore, the design of the bridges (11) is variable as well. This pertains to the shape and the arrangement of the carrying bodies (33) and the positive-locking support (34), and, in particular, the assignment of pins (35) and mounting openings (36) may be transposed. Furthermore, any other  
5 desired type of support, possibly even a purely non-positive support, is possible. Furthermore, the bridge (11) may also be embodied while leaving the workpiece mount (22) at the spindle (8, 9) by means of an insert or a shoe, which is introduced into the gap between the rear side of the workpiece mount (22) and the front side of the headstock (5, 6) and cooperates with corresponding, preferably positive-locking supports on both parts. The workpiece mount (22) is thus supported at  
10 the headstock (5, 6) in a compression-proof and nonrotatable manner and relieves the spindle (8, 9). The connection between the spindle (8, 9) and the workpiece mount (22) may optionally be loosened or opened now.

## LIST OF REFERENCE NUMBERS

	1	Friction welding machine
	2	Frame
	3	Machine bed
5	4	Column
	5	Headstock, large
	6	Headstock, small
	7	Traveling carriage
	8	Spindle, large
10	9	Spindle, small
	10	Bridge, large spindle
	11	Bridge, small spindle
	12	Spindle drive, large
	13	Spindle drive, small
15	14	Drive motor
	15	Drive motor
	16	Intermediate gear, gear mechanism
	17	Flywheel mass, settable
	18	Flywheel mass, additional
20	19	Connection
	20	Coupling means
	21	Gear mechanism, planet gear

	22	Workpiece mount, chuck
	23	Workpiece
	24	Workpiece
	25	Feed drive
5	26	Cylinder, forge cylinder
	27	Forge rod
	28	Cylinder, quick-motion cylinder
	29	Tie rod
	30	Stopping brake
10	31	Carriage guide
	32	Direction of feed
	33	Carrying body, support plate
	34	Support
	35	Pin
15	36	Opening